(12) UK Patent Application (19) GB (11) 2 390 332 (13) A

(43) Date of A Publication 07.01.2004

(21) Application No: 0215168.6

(22) Date of Filing: 01.07.2002

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(51) INT CL[7]:
B41J 2/01

(52) UK CL (Edition W):
B6F FLT

(56) Documents Cited:
US 5535673 A **US 4309452 A**

(58) Field of Search:
UK CL (Edition T) **B6F** FLT
INT CL[7] **B41J** 2/01 11/00
Other: **Online : EPODOC, PAJ, WPI**

(54) Abstract Title: **Multiple pass inkjet printing using UV radiation curable inks with a partial and full ink curing process.**

(57) A method of printing an area of a substrate in a plurality of passes using a curable ink is disclosed. A first pass of ink is deposited, (Fig 1a)said ink is partially cured, a second pass of ink is deposited on the area (Fig 1b) and is then fully cured on the area. During the partial curing step the exposed surface of the partially cured ink may be in a non solidified, substantially liquid or gel form; and the ink adjacent to the substrate may be partially cured. The ink may be radiation curable preferably UV (Ultra Violet) curable. The viscosity and or the temperature of the ink may be reduced prior to deposition of the ink on the substrate. The process is suitable for use with inkjet printers which may be equipped with a plurality of printheads and / or radiation sources.

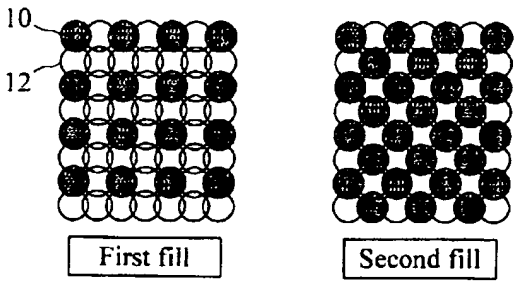

Fig. 1a *Fig. 1b*

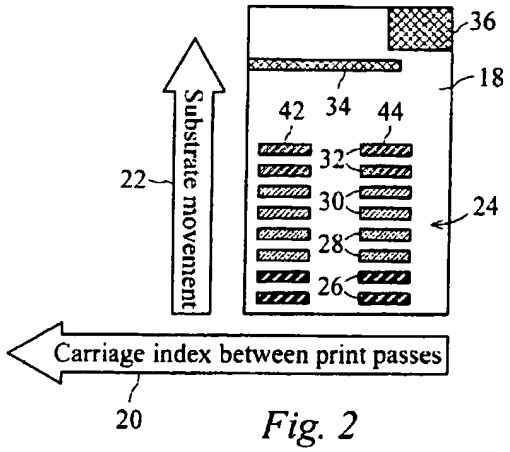

Fig. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

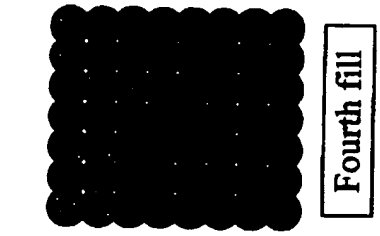

Fig. 1d

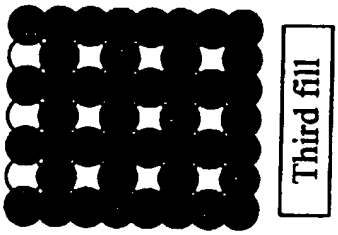

Fig. 1c

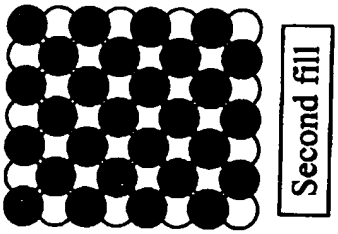

Fig. 1b

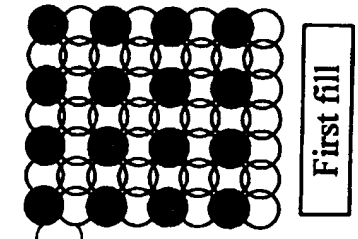

Fig. 1a

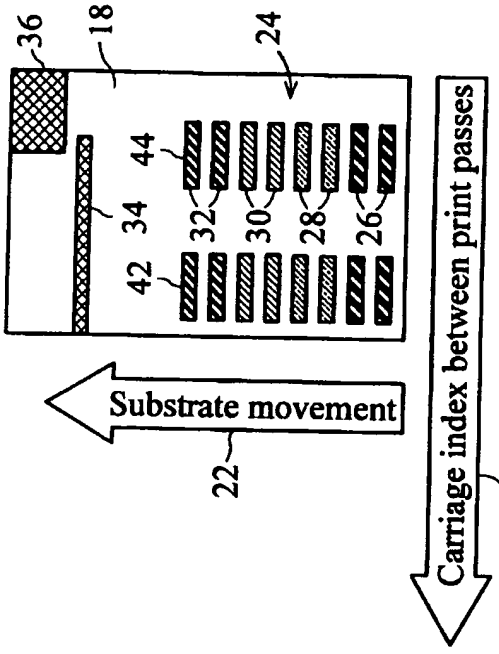

Fig. 2

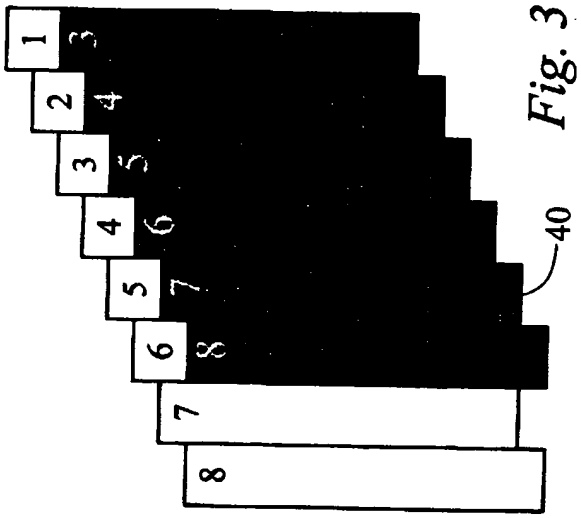

Fig. 3

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PRINTING WITH INK

The invention relates to printing with ink. The invention finds particular, but not exclusive, application in printing with curable ink, in particular with UV curable ink. Particularly preferred examples of the invention relate to the ink-jet printing of curable inks, in particular UV curable ink.

The use of curable inks in printing is well known. Curable ink is preferably to be understood to include ink which solidifies by reaction, in particular for example polymerisation and/or crosslinking. Of particular interest is UV curing ink.

For many curable inks, the ink is solidified by exposing the ink to radiation. In the use of UV curable inks, the ink is deposited on a substrate using a suitable method, and then the ink may be cured by exposing the ink on the substrate to UV light. The exposure of the ink to UV light initiates a chemical reaction which turns the liquid ink into a solid. In other examples, curing is effected using other curing radiation, for example gamma radiation. UV curable inks may be cured using an electron beam, for example from an electron gun. Some inks can be cured simply by applying heat, for example employing an IR source. However, the heat input required to achieve a temperature for rapid cure is often too high for this to be an attractive method.

There are well known UV curing inks that are used in flexographic printers. A flexographic printer is in effect a sophisticated version of a John Bull printing set. The image is typically formed in relief on a rubbery mat, which is pulled around a cylinder. As this cylinder revolves, the ink is applied onto the raised part of the surface via another roller, and the inked surface then is pressed onto the substrate as it goes through the "nip". The inked substrate then passes under a UV lamp, which cures the ink.

Flexographic UV curing inks are relatively viscous and the flexographic process generally produces a much thinner layer of ink on the substrate compared with a piezo inkjet printer, for example.

In an inkjet printing process, the printed image is built up on a substrate by printing drops of ink onto the substrate. The drops of ink are formed by droplets of ink emitted from the nozzles of an inkjet printhead.

The printhead is moved relative to the substrate and the printed image is typically built up in successive passes of one or more printheads across the substrate.

The inkjet process tends to produce structures within the ink film printed on the substrate which are undesirable compared with the flat film produced by, for example, flexographic printing.

In inkjet printing, the ink is delivered onto the substrate as closely spaced rows of droplets, and, as a result, there is a tendency for the ink to form ridges, which are then solidified when exposed to the curing radiation, for example UV light. This effect is especially pronounced when printing onto a low surface-energy substrate such as polypropylene. The ink drops on the substrate tend to pull up from the surface and form balls of ink, which produce balls or ridges on the ink surface. Such structures can reflect light from their surfaces. These balls or ridges produce undesirable glints in the final printed surface, which can look similar to the glints from the surface of a vinyl record disk.

In addition, it is often the case that the cured ink has a much lower surface energy than the liquid ink. In scanning applications, where the inkjet printhead makes several passes over an area of a substrate in order to cover it with ink, it can often be seen that the droplets of liquid ink from later passes do not flow over the cured ink from previous passes. As well as accentuating the ridged structure of the film, this can create two further undesirable effects on the micro-scale:

- Wide, shallow droplets of cured ink on the surface can lie next to deep ball-shaped droplets that have not been able to spread out because they do not wet the

wide shallow droplets. The colour effect is thus impaired because the colour saturation of the wide, shallow droplets is insufficient, and that of the adjacent deep droplets is excessive. The resulting perceived colour is not an "average" because an over-saturated area, for example at the deep drops, results in a different hue. The effect is to restrict the colour gamut achievable, and to reduce the brilliance of the colours.

- Heavy areas of printing will have many droplets landing on top of previous drops. The later arrivals can form balls of ink on the cured surface of earlier drops, either individually or joined up in ridges. This not only accentuates the problem described above, but it also can produce heavy glinting from the surface structure.

Furthermore, the rough surface which can be produced when the drops form balls or ridges on the substrate gives a matt or satin finish to the printed image. This can be undesirable in situations where a gloss finish would be preferred.

Aspects of the present invention seek to mitigate one or more of the problems identified above.

Accordingly, in a first aspect of the invention, there is provided a method of printing an area of a substrate in a plurality of passes using curable ink, the method comprising the steps of: depositing a first pass of ink on the area; partially curing ink deposited in the first pass; depositing a second pass of ink on the area; and fully curing the ink on the area.

In order to reduce the effect of the problems above, we arrange that new ink arriving on the surface can wet the ink that has previously been deposited. One way it might be considered to do this is simply not to cure the ink until it has all been laid down. A problem with that arrangement is that a layer of uncured ink, of low viscosity, tends to spread, that is, the ink drops tend to flow together, producing a smeared effect. Also, ink

droplets on the surface can form an uneven structure of pools and islands of unwetted substrate, thereby reducing detail in the printed image. It is possible, in a multi-pass print, to leave one pass uncured if the density of ink is low enough. However, in practice this will have little beneficial effect, and may in fact exacerbate some of the problems if later drops fall on a thin layer of low surface energy cured ink.

According to an aspect of the invention, it has been found that, by partially setting or curing the ink before the next pass is deposited, better wetting of the ink on the substrate from a previous pass by the subsequent pass can be achieved, while reducing the problem of ink spreading. The partial cure may have the effect of raising the viscosity of the ink. This can have the effect of immobilising the ink on the surface, while leaving the exposed surface of the ink wettable by ink deposited in the second pass.

Preferably, the partial curing step is such that an exposed surface of the partially cured ink is in non-solidified form. Preferably an exposed surface of the partially cured ink is a substantially liquid or gel form. By arranging for the partial curing step to leave the exposed (usually the top) surface of the ink in substantially liquid or gel form, better wetting by the subsequent ink deposited can be achieved.

The exposed surface of the ink might remain liquid or gelled by hindering curing at the surface. This might be done, for example, by blowing oxygen on the exposed surface, where the curing of the ink is inhibited by oxygen. Preferably the partially cured ink is easily wetted by fresh ink applied to its surface.

Preferably the partial setting step effects at least partial curing of the ink adjacent the substrate. In this way spreading of the ink can be reduced. A region of the ink adjacent the substrate may be completely cured. It will be understood that the ink from a particular pass may be directly adjacent the substrate, or there may be one or more previously deposited droplets between the new droplet and the substrate. It should be understood that, where appropriate, reference to ink adjacent the substrate preferably includes ink adjacent a previously printed droplet of ink.

Preferably the ink comprises radiation curable ink, preferably UV curable ink. The UV curable ink may be cured using other types of radiation, for example electron beam radiation or gamma radiation.

Preferably the method comprises partially curing the first passes of ink, a hard curing only being carried out when all the ink has been deposited. Partial curing is most effective when the ink is not exposed to the shorter wavelengths of radiation needed to achieve full cure of the ink surface. The objective in preferred examples of the invention is to solidify, or at least to gel, the layer of ink adjacent the substrate, but to leave the surface liquid or as a gel. This is thought to be possible due to the mechanism of oxygen inhibition. Dissolved oxygen acts to inhibit the curing of the ink, and the action of the initiator is to mop up all the free oxygen and thus to allow the polymerisation to proceed. Near a free surface in air, the oxygen can be replenished quickly by diffusion, so a low dose of radiation can have the desired effect of curing the bottom of the film but not the top surface.

The partial cure is preferably tuned to leave the surface of the ink in a liquid or gel state, while setting the lower layers. For example, for an ink which cures by free radical curing, this can be done by using selected wavelengths and intensity of light according to the type of initiator, for example UV initiator, used in the ink.

Preferably the curing dose of the radiation applied to a region of ink in the partial curing step is not more than 30% of the dose required for a full cure of that ink region. The total dose delivered (J/sqm) is proportional to the value of the intensity of the curing radiation (W/sqm) integrated over the region exposed to the radiation, divided by the product of relative speed of the substrate movement and the width of the region irradiated.

Preferably the wavelength of the radiation used in the partial setting step is greater than about 340 nm. Typically longer wavelength than that used for a full cure would be used, but dependent on the types of initiator used.

The desirable wavelength will depend on the type of ink used, in particular the curing initiators used in the ink. However, the use of long wavelength will tend to cure the part of the drop adjacent the surface more than the exposed surface, which is desirable in that it aids immobilisation of the drop on the substrate. The long wavelength radiation is thought to be more penetrating into ink drops on the substrate and thus effect cure deep in the droplets. At the exposed surfaces of the drops where the inhibitor effect occurs, there is less cure. Normally, a high intensity of short wavelengths would be used which would overwhelm the inhibitor effect at the surface and effect solidification of the ink at the surface.

Different methods could be used to effect the partial cure of the ink.

Preferably the method further includes the step of partially curing ink deposited in the second pass.

Preferably the method further includes the step of depositing at least one further pass of ink and partially curing the deposited ink. Preferably a partial cure is carried out after each and every pass.

Preferably an exposed surface of the ink is not solidified in the partial curing step.

This feature is particularly important and is provided independently. A further aspect of the invention provides a method of printing on an area of a substrate using solidifiable ink, the method comprising: depositing a first pass of ink on the area; partially solidifying the ink such that an exposed surface of the ink is not solidified in the partial solidifying step.

Where the ink is a curable ink, the partial solidification step may be a partial cure step as described above. Alternatively, the ink might not be a curable ink. Such inks include waxy inks which are melted before deposition on the substrate. The ink may comprise a

phase change ink, in which the ink is ejected from the printer in a first (liquid) phase and then changes to a second (solid) phase after deposition.

The relative temperatures of the substrate and the ink could be maintained such that the ink partially solidifies or sets when deposited on the substrate.

It is envisaged that the partial setting step may include cooling an area of the substrate to aid solidification of the lower region of the ink, for example by increasing the viscosity of the ink adjacent the substrate, while leaving the upper regions of the ink unset. It is thought that the ink layer will, in some cases, too thin for the cooling of the substrate to be effective alone in effecting partial solidification.

The method may include the step of heating the ink before depositing the ink on the substrate. Alternatively, or in addition to cooling the substrate, the ink could be heated to increase the temperature difference between the ink and the substrate.

Thus, generally the ink can be printed at high temperature onto a relatively low temperature substrate. The ink cools immediately upon touching the substrate and becomes much more viscous. This would reduce the amount of flow even without a specific partial cure. This method is thought to be particularly effective for inks which change viscosity sharply with temperature.

Thus a further aspect of the invention provides a method of printing an area of a substrate in a plurality of passes using ink, comprising the step of depositing a first pass of ink on the area, wherein the method includes the step of reducing the viscosity of the ink prior to deposition on the substrate.

The reduced viscosity of the ink is easier to print onto the surface, in particular where inkjet printing is used, while the increase in viscosity on the substrate gives the improvements indicated above. The method may include the step of heating the ink prior to its deposition on the substrate.

The ink may comprise thixotropic material. The ink may be subject to shear prior to or during the deposition step, for example a high shear rate effected in the printhead of an inkjet printer. Thus the viscosity can be reduced to allow printing, but the viscosity increases as the deposited ink lies on the substrate.

Thus non-Newtonian inks may be used, for example an ink that behaves much less viscously at high shear rates (for example when expelled from the nozzle or impacting the surface) than at low shear rate (for example when lying on the surface).

Preferably the partially cured or partially solidified ink is such that at least a part of the ink can be displaced by rubbing.

Preferably the partially cured/solidified ink can be smeared or smudged on the surface for example by rubbing a finger or cloth across the printed surface. The ability to smudge or smear the ink is an indication that at least a part of the ink is not fully solidified or cured. This can lead to the improved deposition of further ink onto such a surface.

Thus, in preferred examples, lightly wiping the surface of the partially cured/solidified ink can smear the ink surface. This implies a liquid or gel state of at least a part of the ink.

Sometimes it is seen that the surface of the ink layer can be smeared but will leave a residual layer of ink apparently attached to the surface. It has been observed in some cases that the residual layer is not a hard solid layer.

This feature is of particular importance and is provided independently. Thus a further aspect of the invention provides a method of printing on an area of a substrate using ink, the method comprising: depositing a first pass of ink on the area; and treating the ink, for example by partially solidifying/curing the ink, such that the treated, for example partially cured or partially solidified, ink is such that at least a part of the ink can be

displaced by rubbing.

Preferably the method further comprises the step of depositing a second pass of ink on the area. The second pass is preferably deposited on or adjacent to the partially set ink of the first pass. Preferably, a partial setting, cure or immobilisation of the ink is carried out after each pass, until all of the ink has been deposited for that area.

Preferably the first pass of ink is such that it is substantially wetted by ink of the second pass.

This feature is of particular importance and is provided independently. Thus a further aspect of the invention provides a method of printing an area of a substrate in a plurality of passes using ink comprising the steps of depositing a first pass of ink on the area; and substantially immobilising the ink on the area, wherein the immobilised ink is such that it is substantially wettable by ink of a subsequent pass. The immobilisation may be effected, for example, by partially solidifying or curing the ink.

The wetting may be effected because the surface of the ink droplet is liquid or in gel form compared with the fully cured or solidified ink. Preferably the immobilised ink is readily wettable by the ink deposited in a subsequent printing pass.

The improved wetting of the immobilised ink may be a result of the increased surface energy or surface tension of the immobilised ink compared with the fully cured or solidified ink.

Preferably the partial cure or partial solidification step is such that, when further ink is applied on the partially cured or solidified ink, the further ink forms a substantially flat layer, a substantially glossy layer, and/or a brightly coloured layer compared with the case in which the partial solidification or partial curing is not carried out, for example compared with the case in which a full cure or solidification is carried out before the

further ink is deposited. By looking at the quality of the further ink layer, therefore, it can be possible to determine whether a partial cure and/or partial solidification of the initial ink layer has been effected. For example, if full cure or solidification had taken place before the further ink was deposited, in many cases, there will be significant surface structure seen where the further ink droplets have formed balls on the surface of the original ink layer. By using the partial cure or partial solidification step, a marked reduction in, or absence of, such surface structure may be achievable.

Furthermore, where the partial cure or partial solidification has been carried out before the deposition of the further ink, the migration of ink will be reduced compared with the case where no cure or solidification is carried out before deposition of the further ink.

The amount of initiator in the ink can also be optimised to give the desired rate of curing. Preferably the ink of the subsequent pass has substantially the same composition as that of the first pass.

Preferably the method includes the step of fully curing or solidifying the ink on the area.

Preferably the ink is deposited using an inkjet printer.

A further aspect of the invention provides a printer adapted to print an area by a method as described herein.

A further aspect of the invention provides an apparatus for use in printing an area of a substrate in a plurality of passes using curable ink, comprising: a printhead arranged to deposit a first pass of ink on the area; means (typically a radiation source) for partially curing the ink deposited in the area; a printhead arranged to deposit a second pass of ink on the area; and means (typically a radiation source) for fully curing the ink on the area.

Preferably the apparatus includes a radiation source for partially curing the ink. Preferably the ink comprises UV curable ink.

Preferably the apparatus comprises a radiation source adapted to emit radiation at a dose of not more than 30% of the dose required for a full cure of the ink.

A further aspect of the invention provides apparatus for printing on an area of a substrate using solidifiable ink, the apparatus comprising: a printhead arranged to deposit a first pass of ink on the area; and means for partially solidifying the ink such that an exposed surface of the ink is not solidified in the partial solidifying step.

The apparatus may comprise means for cooling an area of the substrate. The apparatus may comprise means for heating the ink before depositing the ink on the substrate. The apparatus may comprise means for reducing the viscosity of the ink prior to deposition on the substrate. The ink may comprise thixotropic material.

A further aspect of the invention provides apparatus for printing on an area of a substrate using ink, the apparatus comprising: a printhead for depositing a first pass of ink on the area; and means (typically a radiation source) for partially solidifying/curing the ink such that the partially cured or partially solidified ink is such that at least a part of the ink can be displaced by rubbing.

Preferably the apparatus is further adapted to deposit a second pass of ink on the area.

A further aspect of the invention provides apparatus for printing an area of a substrate in a plurality of passes using ink comprising: a printhead for depositing a first pass of ink on the area; and means (typically a radiation source) for substantially immobilising the ink on the area, wherein the immobilised ink is such that it is substantially wetted by ink of a subsequent pass.

Preferably the apparatus comprises a radiation source for substantially fully curing the ink on the area.

A further aspect of the invention provides the use of a heated ink in the printing of a substrate. A further aspect of the invention provides the use of a thixotropic ink in the printing of a substrate.

A further aspect of the invention provides a printer carriage for a printer, the printer carriage comprising one or more printheads, a radiation source for partially curing ink emitted by the printheads, and a radiation source for substantially fully curing the ink.

Preferably the radiation source is arranged to fully cure the ink on an area of a printed substrate only after substantially all of the ink has been deposited onto that area.

The invention further provides a printer control device for controlling a printer to effect printing according to a method as described herein.

The invention also provides a computer program and a computer program product for carrying out any of the methods described herein and/or for embodying any of the apparatus features described herein, and a computer readable medium having stored thereon a program for carrying out any of the methods described herein and/or for embodying any of the apparatus features described herein.

The invention also provides a signal embodying a computer program for carrying out any of the methods described herein and/or for embodying any of the apparatus features described herein, a method of transmitting such a signal, and a computer product having an operating system which supports a computer program for carrying out any of the methods described herein and/or for embodying any of the apparatus features described herein.

The invention extends to methods and/or apparatus substantially as herein described with reference to the accompanying drawings.

Any feature in one aspect of the invention may be applied to other aspects of the

invention, in any appropriate combination. In particular, method aspects may be applied to apparatus aspects, and vice versa.

Preferred features of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

Figures 1a to 1d show the build up of dots in a four-fill printing system;
Figure 2 illustrates the configuration of a printhead used in an example; and
Figure 3 illustrates the printing image.

In the examples described below, a "100% solids" ink is used. After the ink is jetted onto the substrate, it all becomes solidified by exposure to UV radiation. The ink comprises a monomer/oligomer mix with a UV initiator. When the ink is exposed to UV light, it initiates a polymerisation and crosslinking reaction which solidifies the liquid ink.

The examples described below, a Sericol UviJet UV curable ink is used. After a pass of ink has been deposited, the ink on the substrate is partially cured using a UV lamp. The partial curing lamp is a Philips Special HID lamp HPR 125W and the radiation dose from the from the partial curing lamp is not enough to completely cure the ink droplets on the substrate, but partially cures the droplet enough so that it does not interact with adjacent droplets on the substrate. The upper surface of the droplet, however, remains liquid or gels so that the ink is effectively immobilised. Once all of the ink has been deposited on the surface, a UV lamp is used to complete the cure of the ink droplets.

The example described below uses a scanning inkjet printing system, for example the EAGLE 44 printer of Inca Digital Printers Limited. In this system any given area of the substrate is repeatedly passed over by printheads to build up the print image.

Figures 1a to 1b show a typical fill pattern of a single colour using four fill printing on the EAGLE 44 printer.

The figures show that the printed image comprises a generally square array of printed dots (represented by circles). Each fill shows a set of positions in which drops of ink can be printed by one printhead. The shaded circles 10 show drops which are printed in that particular fill: in one pass by one printhead. Open circles 12 show the position of drops to be printed in subsequent fills.

In the printer arrangement described herein, the four fills are carried out in two passes of the printhead arrangement over the substrate. In this example, the first and second fills are laid down in the first pass; the third and fourth in the second pass.

The drops are printed using a printhead having one or more rows of printing nozzles which emit droplets of ink. In this example, the distance between the nozzles of the row is twice the drops spacing for the printed image, and thus the printhead prints on every other drop. In the first pass, as shown in Figures 1a and 1b, square grids of drops are printed, each grid having a pitch which is twice the drop pitch for the completed printed image. In the second fill, shown in Figure 1b, drops are printed diagonally between the drops printed in the first fill.

The second pass, shown in Figures 1c and 1d, fills in the remaining drops.

It might appear that the first and second fills of printing would not cause a problem of interaction between the drops because the drops do not touch or overlap as shown in Figure 1b. However, in practice, there are errors in drop placement which mean that there will be overlaps, and therefore potential interactions between drops on the surface.

Figure 2 shows a top view of a printer carriage 18 arrangement. The printer carriage is mounted for lateral movement 20 relative to a substrate under the printhead (not shown). The substrate is mounted for movement 22 relative to the carriage. The movement of the substrate is substantially perpendicular to the lateral movement of the carriage 18.

In the carriage 18 are arranged sixteen printheads in two lines of eight. Each line of eight

printheads includes two cyan 26, two magenta 28, two yellow 30 and two black 32 printheads.

The printheads used are Spectra Nova 256 printheads.

The two lines of printheads are here laid out one "stripe width" apart, that is the distance between the lines is substantially equal to the active width of each printhead. It would also be possible to use other geometries.

The carriage also includes a "partial cure" lamp 34. An example of a suitable lamp is a Philips Special HID lamp HPR 125W which gives radiation having a wavelength greater than 340 nm. The partial cure lamp 34 is arranged "behind" the printheads 24 so that the substrate moving under the carriage first passes under the printheads 24 and then under the partial cure lamp 34.

The carriage 18 further includes a "full cure" lamp 36. This curing lamp is a GEW NUVA mercury arc lamp. The curing lamp is arranged behind the partial cure lamp, and is also laterally displaced from the printheads 24 and the partial cure lamp 34 so that the curing lamp 36 only passes over an area of the substrate after the printing by the printheads 24 is complete.

Each print stroke takes the substrate under the printheads then the UV lamps. Between each print stroke the print carriage 18 moves to the left 20 by a certain amount depending on the print mode chosen. It can be seen that the first ink layers printed on the substrate only get exposed to the partial cure lamp 34, and that the printed substrate does not pass under the full curing lamp 36 until all the ink has been jetted for that particular area of the substrate.

Figure 3 shows the build-up of the image. Each "stripe" 40 is numbered in order of the print pass when it was laid down, and for clarity each print pass is shifted down by a fixed amount (the higher up stripes being laid down first by the printheads in column 42).

One possible "four fill" printing scheme is illustrated.

The arrangement builds up the printed image in two passes effecting four fills as shown in Figures 1a to d. The first pass (shown in Figures 1a and 1b) is printed using the printheads of the left hand column 42 of printheads 24. The first and second fills are printed by the two sets of cyan, magenta, yellow and black printheads which are arranged to give the desired printed image. The second pass over the area (Figures 1c and 1d) is printed using the sets of printheads in the right hand column 44 of printheads 24.

In the first print pass, only the left-hand column 42 of printheads 24 is used. On the second pass, the left hand column 42 again prints after the carriage 18 moves a "stripe" to the left. Then the carriage moves another stripe to the left and the third pass is printed by both columns 42, 44 of printheads 24. The fourth, fifth, sixth, seventh and eighth passes are then printed, each preceded by a carriage movement to the left of a print stripe.

The print carries on, but is shown as if interrupted after pass 8. This scheme of printing is used to achieve complete coverage of the area using the layout of printheads shown, but other arrangements could be used.

It will be seen that after each pass, the printed ink is set using the partial cure lamp 34. It will be seen that an area of the printed image is always completely laid down before being fully cured using the full curing lamp 36.

The following example describes a method in which the partial solidification of the ink before the final cure is carried out by heating the ink.

A similar printhead arrangement is used to that described above with reference to Figures 1 to 3. In this case, however, an ink is used which has a viscosity of above 50 centipoises at about 20 to 25 degrees C, and a viscosity of about 22 cp at 60 degrees C. The substrate to be printed is arranged on a printing bed. The substrate may have a surface temperature of about 20 to 25 degrees C. Such a bed may include a cooling system, for example if

there are significant fluctuations in the temperature of the local environment.

The ink is heated to about 60 degrees C and jetted onto the cool surface. The cool surface effects a local increase in the viscosity of an ink droplet landing on the surface and the increase in viscosity effects partial solidification of the droplet, thereby reducing ink spreading. The partial cure lamp might not be used in this example.

It will be understood that the present invention has been described above purely by way of example, and modification of detail can be made within the scope of the invention.

Each feature disclosed in the description, and (where appropriate) the claims and drawings may be provided independently or in any appropriate combination.

CLAIMS:

1. A method of printing an area of a substrate in a plurality of passes using curable ink, the method comprising the steps of:
depositing a first pass of ink on the area;
partially curing ink deposited in the first pass;
depositing a second pass of ink on the area; and
fully curing the ink on the area.

2. A method according to claim 1, wherein the partial curing step is such that an exposed surface of the partially cured ink is in non-solidified form.

3. A method according to claim 2, wherein the partial curing step is such that an exposed surface of the partially cured ink is in substantially liquid or gel form.

4. A method according to any preceding claim, wherein the partial curing step effects at least partial curing of the ink adjacent the substrate.

5. A method according to any preceding claim wherein the ink comprises radiation curable ink, preferably UV curable ink.

6. A method according to claim 5, wherein the dose of the curing radiation applied to a region of ink in the partial curing step is not more than 30% of the dose required for a full cure of that ink region.

7. A method according to claim 5 or claim 6, wherein the wavelength of the radiation used in the partial curing step is greater than about 340 nm.

8. A method according to any preceding claims, further including the step of partially curing ink deposited in the second pass.

9. A method according to any preceding claim, further including the step of

depositing at least one further pass of ink and partially curing the deposited ink.

10. A method according to any preceding claim wherein an exposed surface of the ink is not solidified in the partial curing step.

11. A method of printing on an area of a substrate using solidifiable ink, the method comprising:
depositing a first pass of ink on the area;
partially solidifying the ink such that an exposed surface of the ink is not solidified in the partial solidifying step.

12. A method of printing an area of a substrate in a plurality of passes using ink, comprising the step of depositing a first pass of ink on the area, wherein the method includes the step of reducing the viscosity of the ink prior to deposition on the substrate.

13. A method according to any preceding claim, including the step of heating the ink before depositing the ink on the substrate.

14. A method according to any preceding claim, wherein the partially cured or partially solidified ink is such that at least a part of the ink can be displaced by rubbing.

15. A method of printing on an area of a substrate using ink, the method comprising:
depositing a first pass of ink on the area; and
partially solidifying/curing the ink such that the partially cured or partially solidified ink is such that at least a part of the ink can be displaced by rubbing.

16. A method according to any preceding claim, further comprising the step of depositing a second pass of ink on the area.

17. A method according to claim 16, wherein the first pass of ink is such that it is substantially wetted by ink of the second pass.

18. A method of printing an area of a substrate in a plurality of passes using ink comprising the steps of
depositing a first pass of ink on the area; and
substantially immobilising the ink on the area,
wherein the immobilised ink is such that it is substantially wettable by ink of a subsequent pass.

19. A method according to any preceding claim, further including the step of fully curing or solidifying the ink on the area.

20. A method according to any preceding claim, wherein the ink is deposited using an inkjet printer.

21. A printer adapted to print an area by a method according to any preceding claim.

22. Apparatus for use in printing an area of a substrate in a plurality of passes using curable ink, comprising:
a printhead arranged to deposit a first pass of ink on the area;
means (typically a radiation source) for partially curing the ink deposited in the .
a printhead arranged to deposit a second pass of ink on the area; and
means (typically a radiation source) for fully curing the ink on the area.

23. Apparatus according to claim 22 wherein the ink comprises radiation curable ink, preferably UV curable ink.

24. Apparatus according to claim 23, comprising a radiation source adapted to emit radiation at a dose of not more than 30% of the dose required for a full cure of the ink.

25. Apparatus for printing on an area of a substrate using solidifiable ink, the apparatus comprising:
a printhead arranged to deposit a first pass of ink on the area;
means for partially solidifying the ink such that an exposed surface of the ink is not solidified in the partial solidifying step.

26. Apparatus according to any of claims 22 to 25, including means for heating the ink before depositing the ink on the substrate.

27. Apparatus according to any of claims 22 to 26, including means for reducing the viscosity of the ink prior to deposition on the substrate.

28. Apparatus for printing on an area of a substrate using ink, the apparatus comprising:
a printhead for depositing a first pass of ink on the area; and
means (typically a radiation source) for partially solidifying/curing the ink such that the partially cured or partially solidified ink is such that at least a part of the ink can be displaced by rubbing.

29. Apparatus according to any of claims 22 to 28, further adapted to deposit a second pass of ink on the area.

30. Apparatus for printing an area of a substrate in a plurality of passes using ink comprising:
a printhead for depositing a first pass of ink on the area; and
means (typically a radiation source) for substantially immobilising the ink on the area,
wherein the immobilised ink is such that it is substantially wetted by ink of a subsequent pass.

31. Apparatus according to any of claims 22 to 30, including a radiation source for substantially fully curing or solidifying the ink on the area.

32. A printer carriage for a printer the printer carriage comprising one or more printheads, a radiation source for partially curing ink emitted by the printheads, and a radiation source for substantially fully curing the ink.

33. A printer carriage according to claim 32, wherein the radiation source is arranged to fully cure the ink on an area of a printed substrate only after substantially all of the ink has been deposited onto that area.

34. A printed substrate printed by a method according to any of claims 1 to 21 or using an apparatus according to any of claims 22 to 33.

35. A printer control device for controlling a printer to effect printing according to a method of any of claims 1 to 21.

36. A method being substantially as herein described having reference to the accompanying drawings.

37. Apparatus being substantially as herein described having reference and as shown in one or more of the accompanying drawings.

Application No:	GB 0215168.6	**Examiner:**	Gareth Jones
Claims searched:	1 - 10, 22 - 24, 32 - 35,	**Date of search:**	4 September 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): B6F : FLT

Int Cl (Ed.7): B4IJ : 2/01, 11/00

Other: Online : EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,Y	US 5,535,673	(CORNING Inc.) See col 3 lines 46 - 56, col 4 lines 11 - 14, col 5 lines 25 - 33, col 6 lines 13 - 31, col 7 lines 19 - 29, col 8 lines 15 - 25, col 10 6 - 17. See also claims 1, 7 and 26 and Fig 2	1 - 3, 5, 7 - 10.
Y	US 4,309,452	(GAF Corp.) See col 1 lines 45 - 62, col 2 lines 16 - 59, col 3 lines 23 - 38. See also claim 1.	1 - 5, 7, 8, 10.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.